

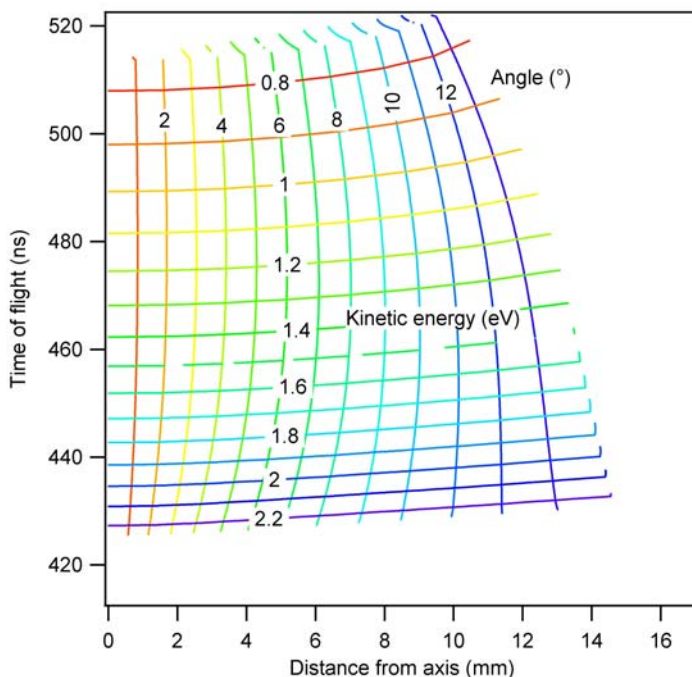
Chemical Potential in the THEMIS 1000

Technical Note

The THEMIS time of flight spectrometers deliver raw data consisting of flight time and position information for each detected electron. Due to the high electron-optical quality of the THEMIS lens, this data can be directly interpreted as energy and angle data, with full angle and energy resolution. For qualitative or relative information, this time/position data does not have to be transformed into energy/angle values.

For quantitative interpretation of the data, it needs to be transformed using a look-up diagram (or transformation matrix) like the one shown below. This transformation matrix is calculated with very high precision using an electron optical simulation program.

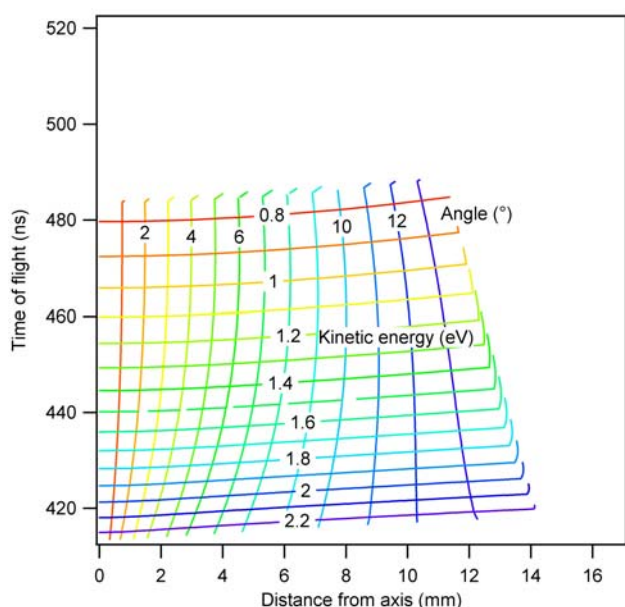
Unfortunately, one unknown quantity in this calculation is the potential difference between the spectrometer and the sample. This difference arises due to the different work functions or chemical potentials of the spectrometer and the sample.



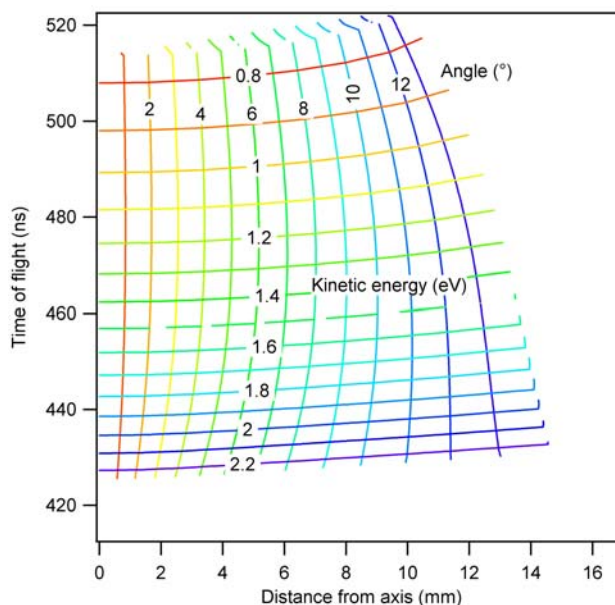
Conversion of time/position
data into energy/angle values.
Calculated for $R = 0.1$, $\pm 13^\circ$
mode. Sample on the same
potential as the spectrometer.

At small kinetic energies, this potential difference can significantly influence the time of flight. It also leads to the effect that the electrons pass through the lens with a different voltage than assumed for the calculation of the transformation matrix.

The effect of a 0.5 eV difference in chemical potential is seen in the look-up diagrams below. It has been calculated with the same conditions, only the sample potential has been set to -0.5 eV to simulate this chemical potential difference. For comparison, the non-biased look-up diagram is shown again.



Conversion of time/position data into energy/angle values. Calculated for $R = 0.1$, $\pm 13^\circ$ mode. Sample on -0.5 eV relative to the spectrometer.



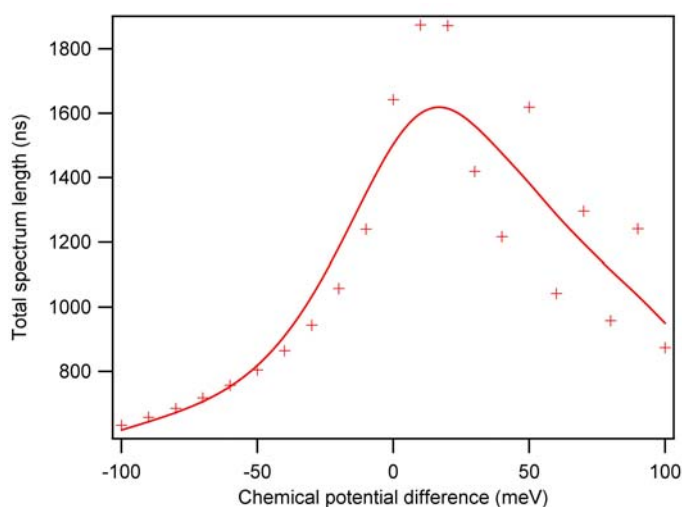
Non-biased diagram (from the last page) shown for comparison.

In order to compensate this effect of the chemical potential difference, the THEMIS spectrometer can be completely biased to a voltage U_{phi} . This voltage is applied to all lens elements including the first element as well as the detector. If U_{phi} is set such that the difference in chemical potential is zero, then the calculated transformation matrix can be applied to the data and will give the quantitatively correct energy and angle values.

The problem is to find this correct value of U_{phi} , since typically the work function of the sample is unknown. We suggest the following procedure for the adjustment of U_{phi} . For any given U_{phi} , there will be two characteristic flight times:

- a) T_{max} : the maximum detected flight time, associated with the slowest electrons that can reach the detector. If the chemical potential difference has a repelling effect, then these electrons have to have sufficient kinetic energy to overcome this barrier in order to enter the spectrometer.
- b) T_{min} : the minimum flight time, associated with the fastest electrons in the spectrum. These are typically the electrons at the Fermi edge, or any other characteristic feature in the density of states.

The plot shown below displays the total spectrum length $T_{\text{total}} = T_{\text{max}} - T_{\text{min}}$ as a function of the chemical potential difference, taken from an electron optical simulation of a spectrum from 0.001 eV to 1 eV kinetic energy emitted from the sample. T_{total} shows a pronounced maximum at the correct setting of U_{phi} where the difference in chemical potential is zero.



Total spectrum length as a function of the chemical potential difference. The simulated data (crosses) shows significant scatter due to the limited simulation precision. The line is meant as a guide to the eye.



The precision of the simulation for these small kinetic energies is limited, which leads to a significant scatter in the simulated data points. Nevertheless, the simulation shows that this method enables one to set the chemical potential difference to a value smaller than 15 meV by adjusting U_{phi} such that the spectrum has maximum length in time. After this adjustment has been done, the calculated transformation matrix (calculated for a chemical potential difference of 0 eV) can be applied to the data.

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